Fluid mechanics

Lecture 1:

Introduction and basic principles

General information

- Lectures: prof.dr.ir. J. Westerweel [@wstrwl]
  Tuesday 13:45-15:30
  Thursday 15:45-17:30
- Instruction: dr. R. Delfos
  Wednesday 13:45-15:30
- Book: Fluid Mechanics
  by Frank M. White
- Other sources: Multimedia Fluid Mechanics DVD (Cambridge)
  www.efluids.com
- Exam: April ??, 2012
  closed book exam, equation sheet provided
- Discussion: BlackBoard
  Twitter: #wb1225

Fluid mechanics in technology


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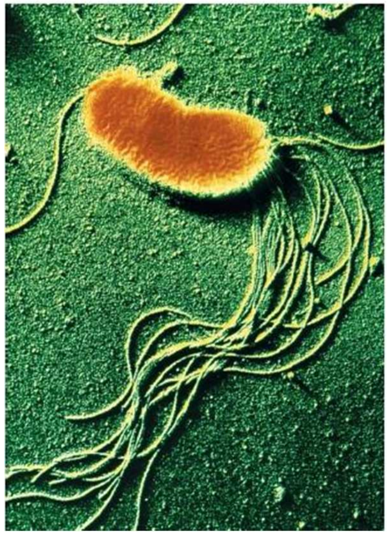
Fluid mechanics in nature



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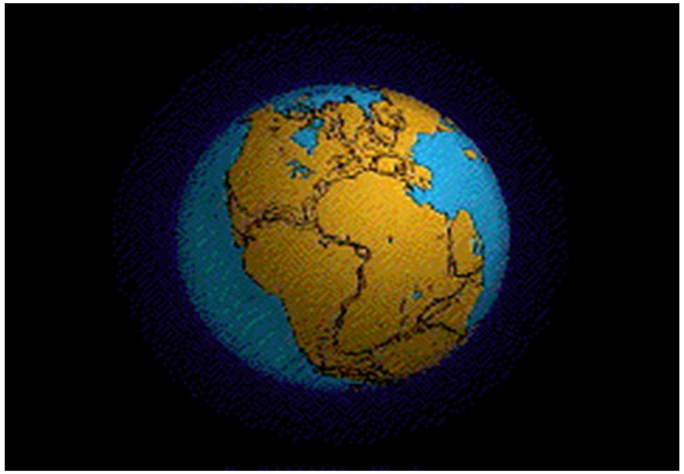

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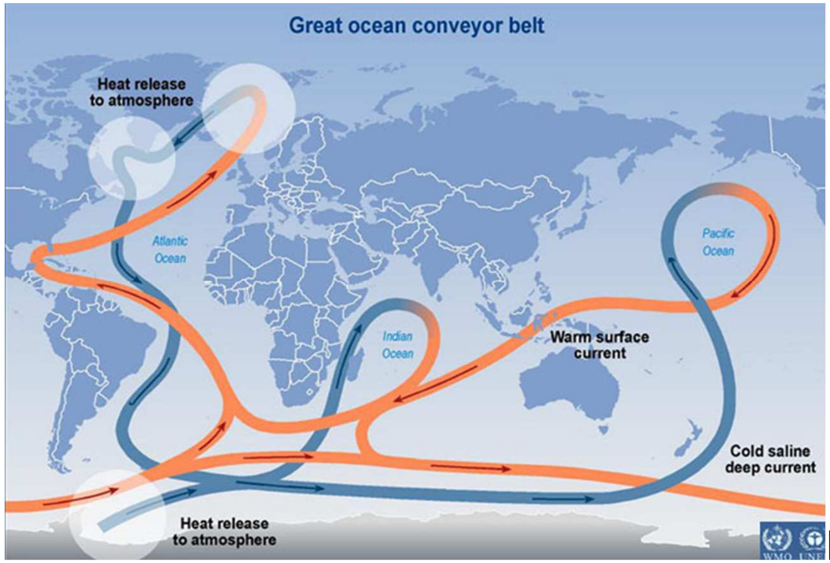
Environmental fluid mechanics



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Environmental fluid mechanics

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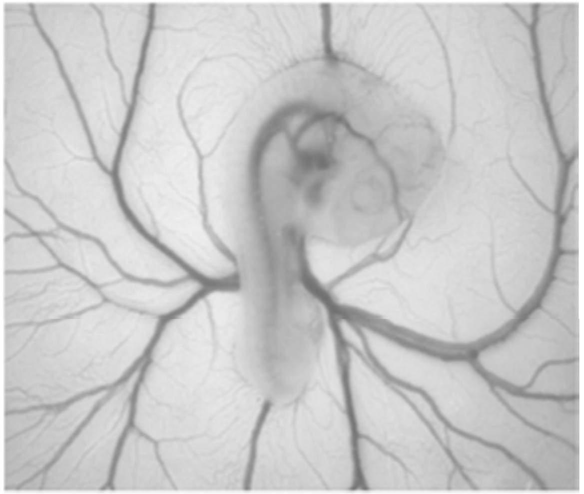
Biological fluid dynamics



chicken embryo

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wiggly take off

Fluid mechanics in sports

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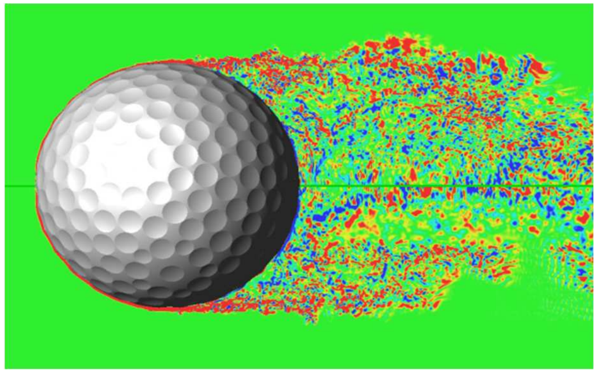

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A 100 years ago and Today

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Franz Reichelt, 1912

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Jeb Corliss, 2011

Fluid mechanics in daily life

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What is a fluid?

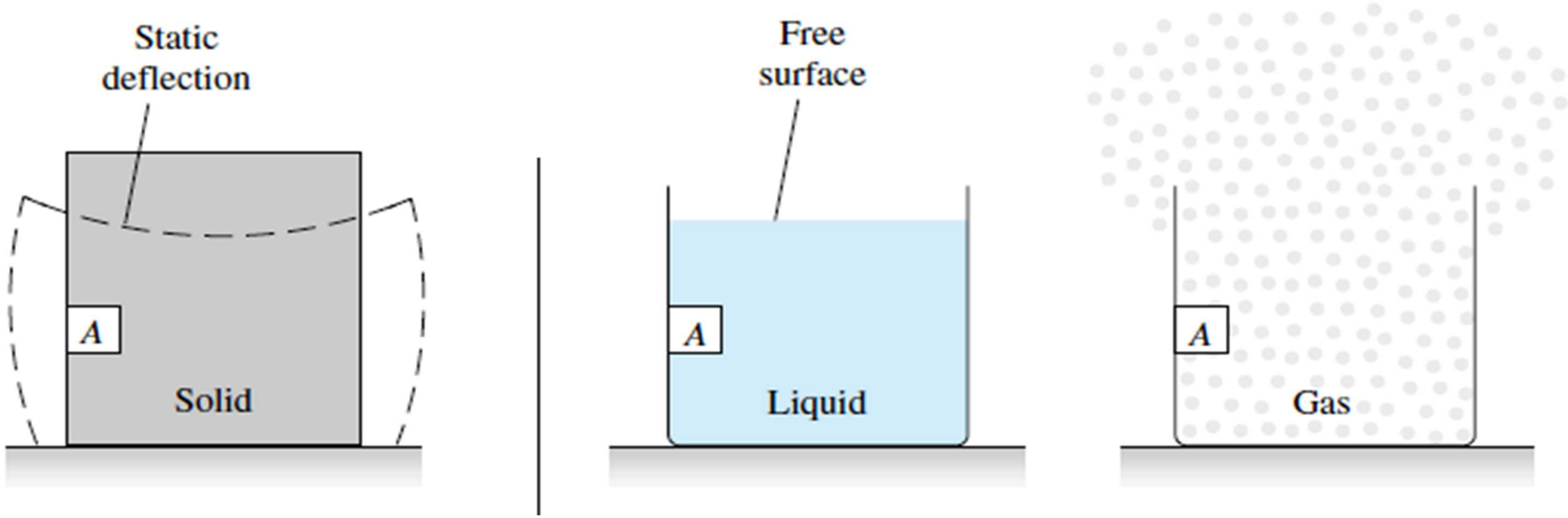
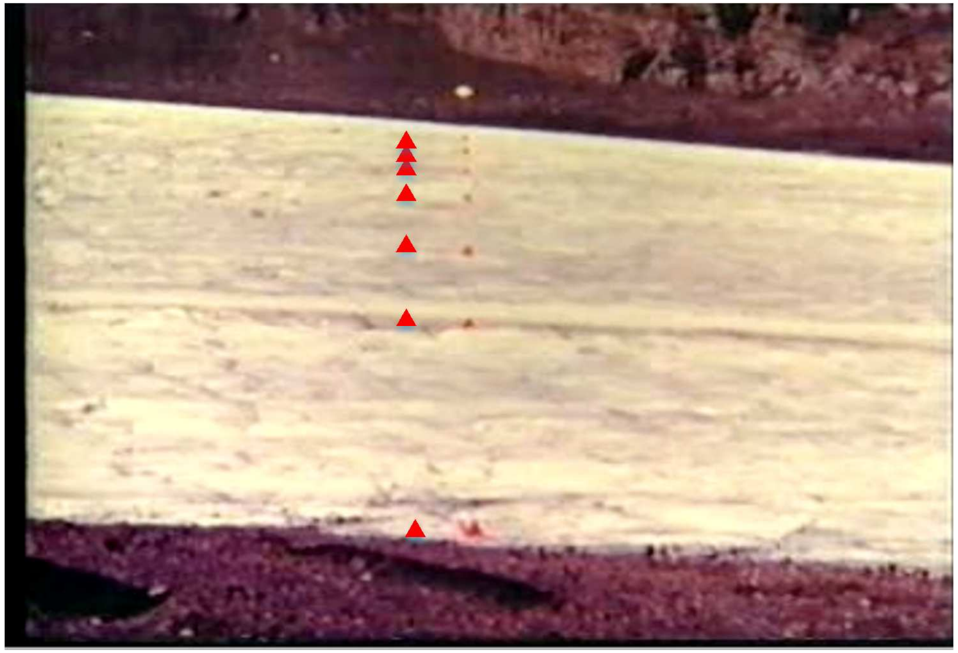


Image from Frank M. White - *Fluid Mechanics*

Fluid or solid?

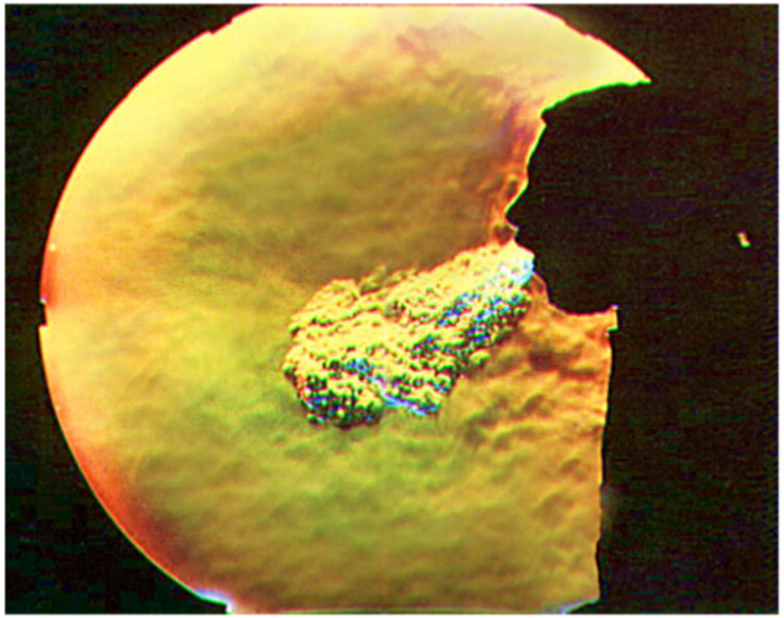
Glacier flow



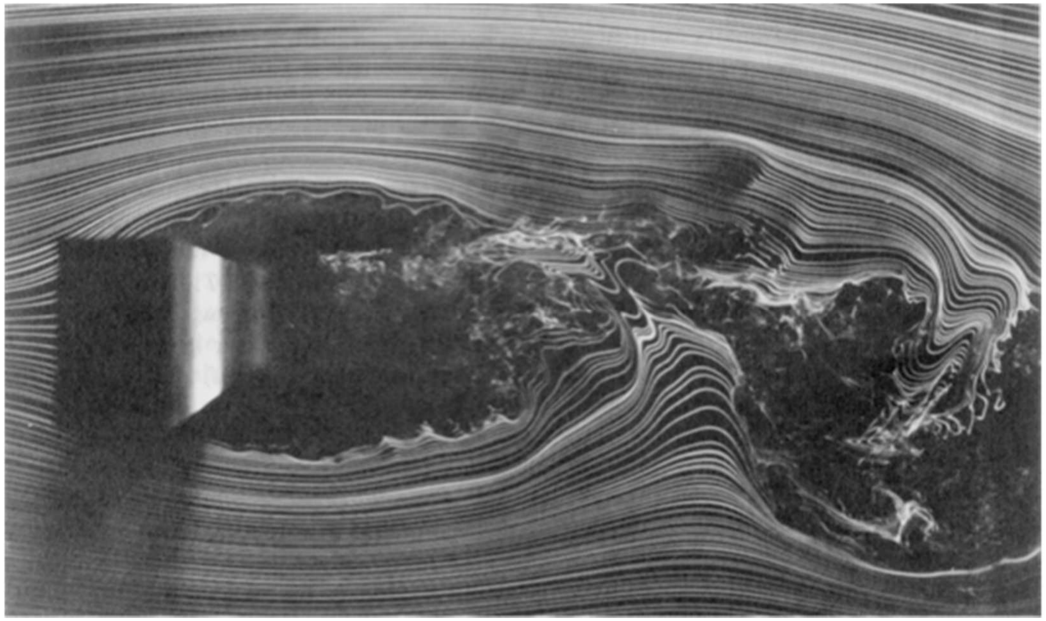
original

two years later

Flow visualization



Gary Settles



Van Dyke, Album of Fluid Motion
www.efluids.com
Gallery of Fluid Motion (Physics of Fluids)

[26]

Fluid properties

• Pressure	p	[Pa]
• Density	ρ	[kg / m^3]
• Temperature	T	[K]
• Thermodynamic properties:		
• internal energy e, enthalpy h, entropy s		
• specific heat	c_p, c_v	[J / K kg]
• Transport properties:		
• viscosity	μ	[Pa s]
• thermal conductivity	k	[W / K m]

Viscosity of common fluids

Fluid	μ, kg/(m · s)†	Ratio $\mu/\mu(H_2)$	ρ, kg/m^3	ν m^2/s†	Ratio $\nu/\nu(Hg)$
Hydrogen	8.8 E–6	1.0	0.084	1.05 E–4	920
Air	1.8 E–5	2.1	1.20	1.51 E–5	130
Gasoline	2.9 E–4	33	680	4.22 E–7	3.7
Water	1.0 E–3	114	998	1.01 E–6	8.7
Ethyl alcohol	1.2 E–3	135	789	1.52 E–6	13
Mercury	1.5 E–3	170	13,580	1.16 E–7	1.0
SAE 30 oil	0.29	33,000	891	3.25 E–4	2,850
Glycerin	1.5	170,000	1,264	1.18 E–3	10,300

$$\mu = \rho \nu$$

μ = dynamic viscosity [kg/(m s)] = [Pa s]

ν = kinematic viscosity [m^2 / s]

The pitch drop experiment

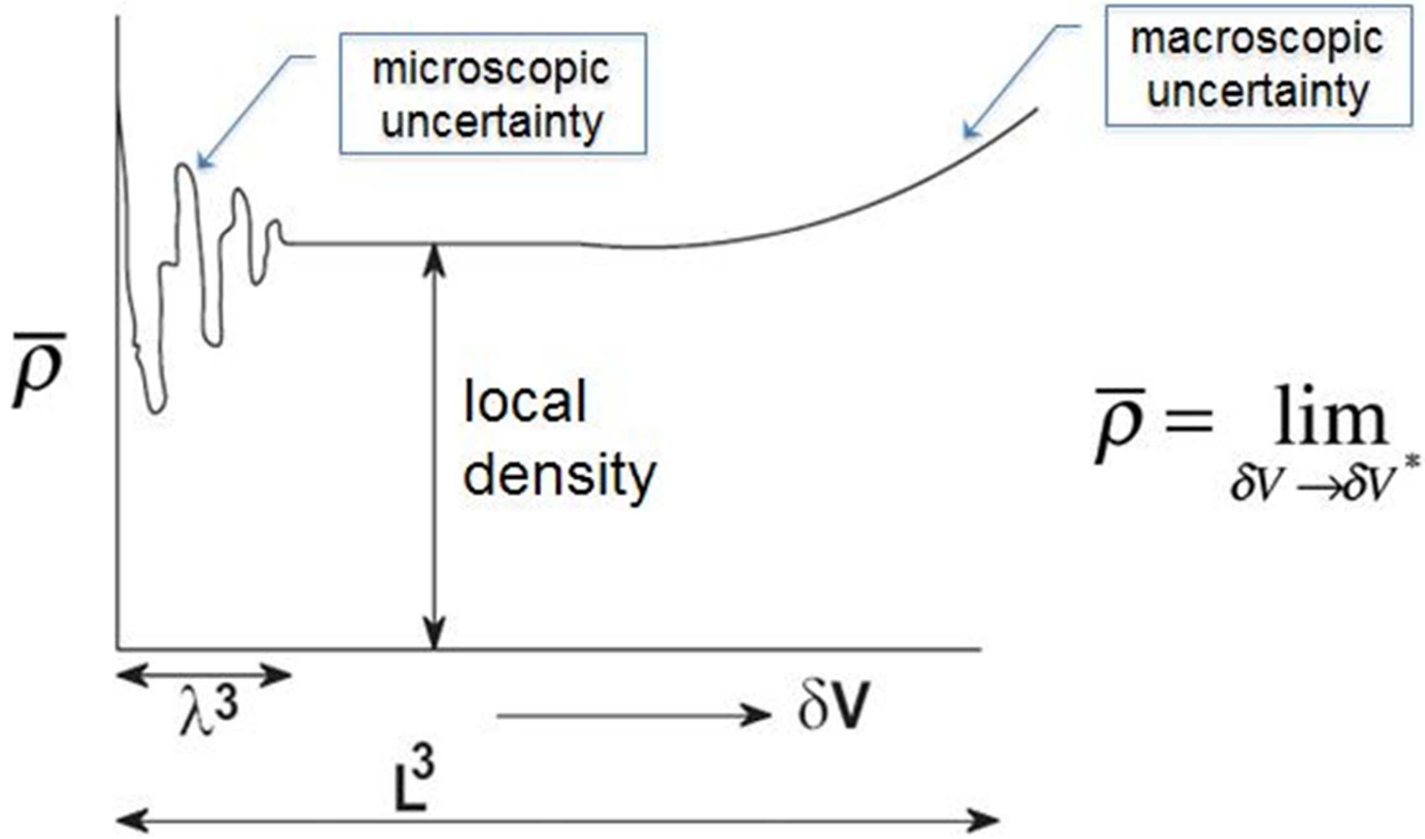
Year	Event
1930	The stem was cut
1938 (Dec)	1st drop fell
1947 (Feb)	2nd drop fell
1954 (Apr)	3rd drop fell
1962 (May)	4th drop fell
1970 (Aug)	5th drop fell
1979 (Apr)	6th drop fell
1988 (Jul)	7th drop fell
2000 (28 Nov)	8th drop fell

viscosity: $\mu = (2.3 \pm 0.5) \times 10^{8}$ Pa s
(water: $\mu = 1.0 \times 10^{-3}$ Pa s)

http://drop.physics.uq.edu.au/PitchDropLive

Edgeworth et al. Eur. J. Phys. 5 (1984) 198-200

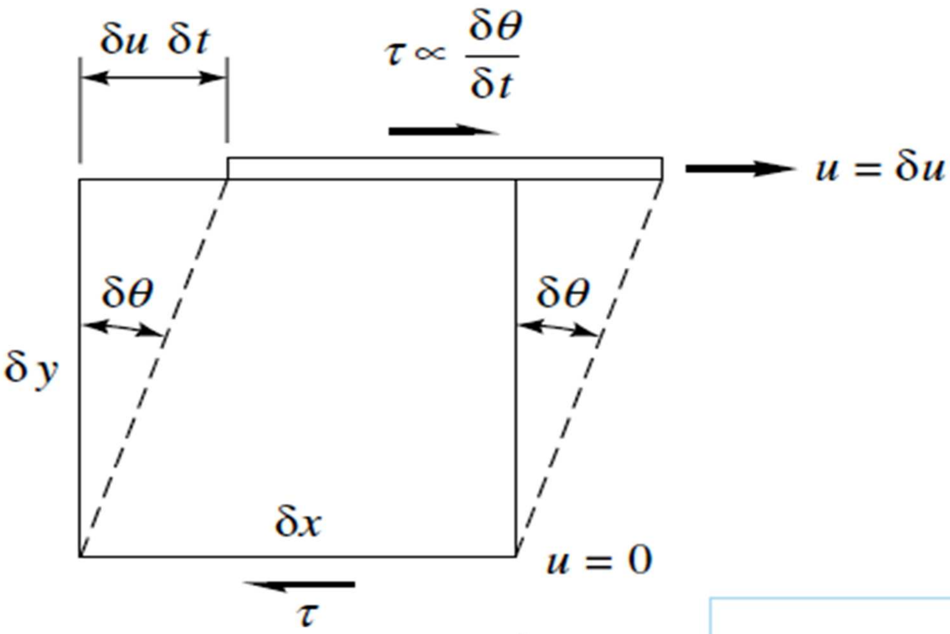
Continuum hypothesis



$$\bar{\rho} = \lim_{\delta V \to \delta V^*} \frac{\delta m}{\delta V}$$

MMFD-DVD page 146

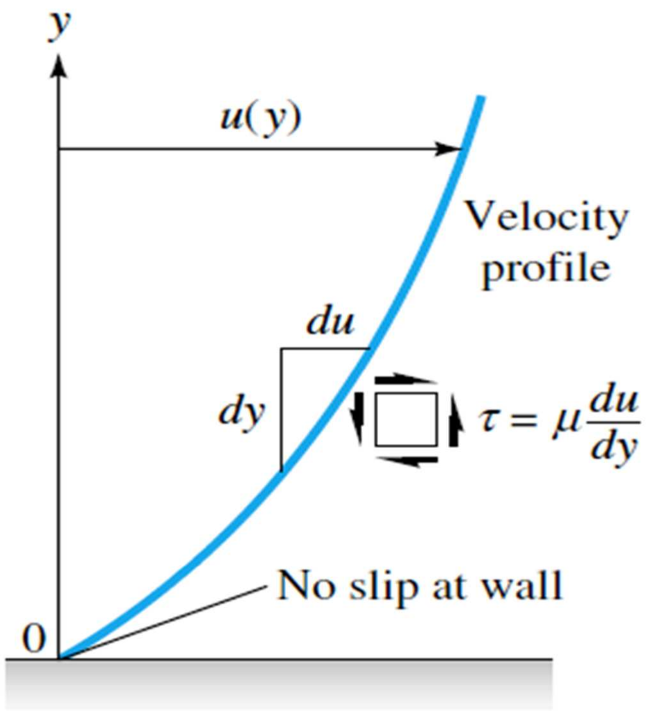
Shear stress



deformation (strain) [s^{-1}]

$$\frac{d\theta}{dt} = \frac{du}{dy} \quad (\text{small } \theta)$$

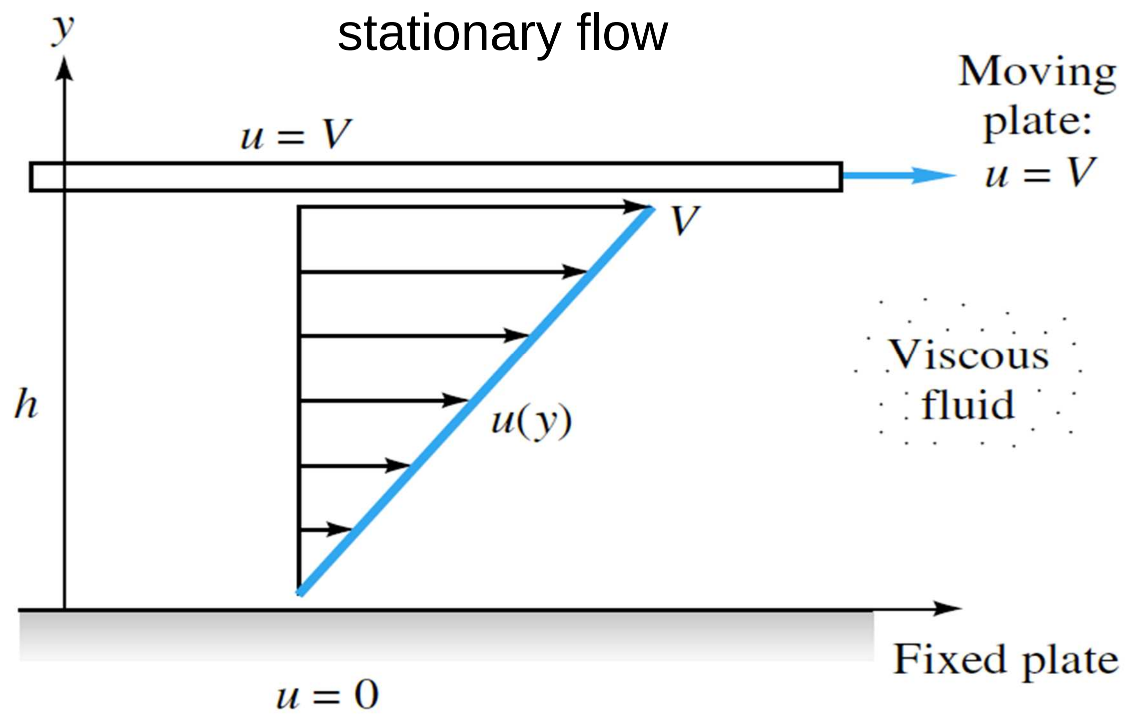
$$\tau = \mu \frac{du}{dy}$$



shear stress [Pa]

Couette flow

stationary flow



$$\tau = \mu \frac{du}{dy}$$

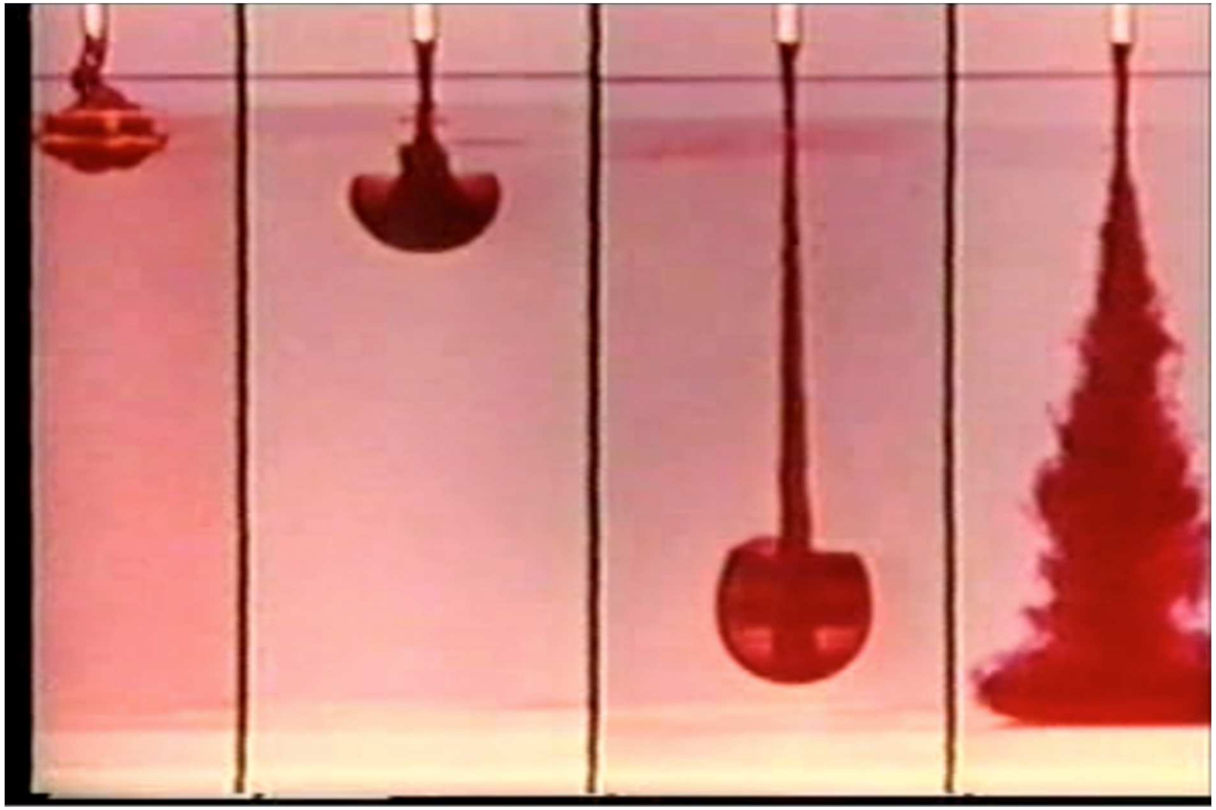
Newtonian fluid ($\mu = \text{const}$) :

$$\frac{\tau}{\mu} = \frac{du}{dy} = \text{const} \quad \Rightarrow \quad u(y) = a + by \quad \Rightarrow \quad u = V\frac{y}{h}$$

Effect of viscosity

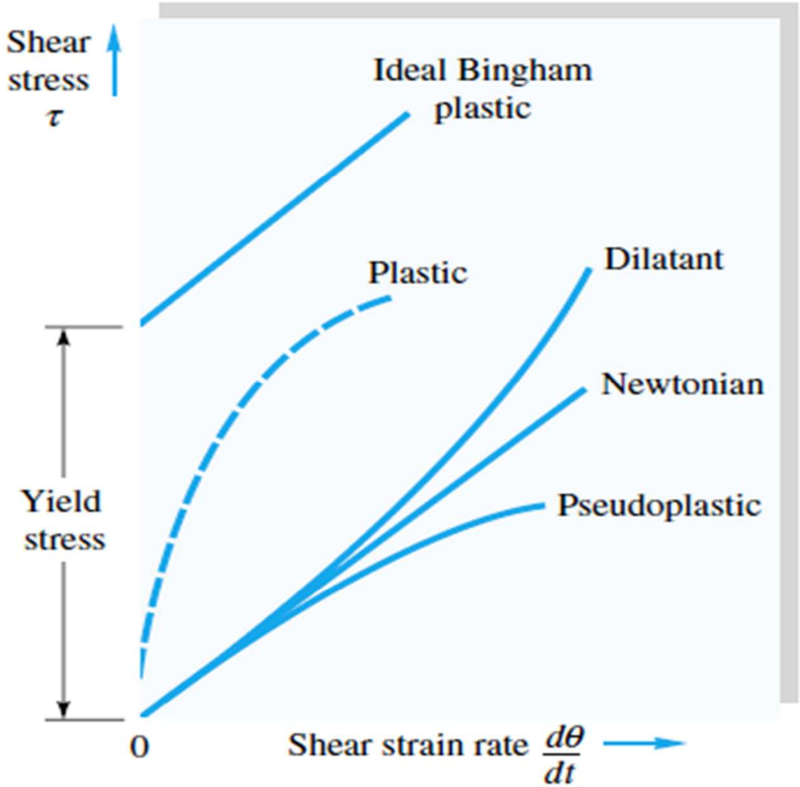
Reynolds number

$$Re = \frac{\rho V L}{\mu}$$

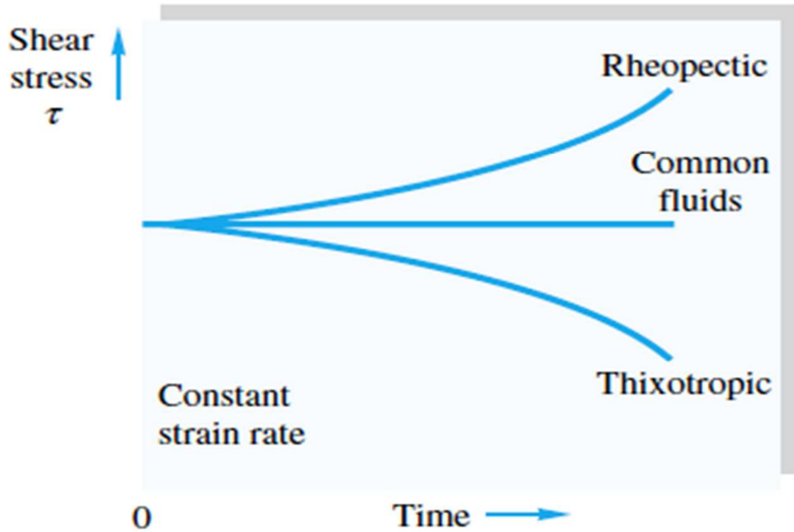


Re = 0.05 10 200 3000

Non-Newtonian fluids

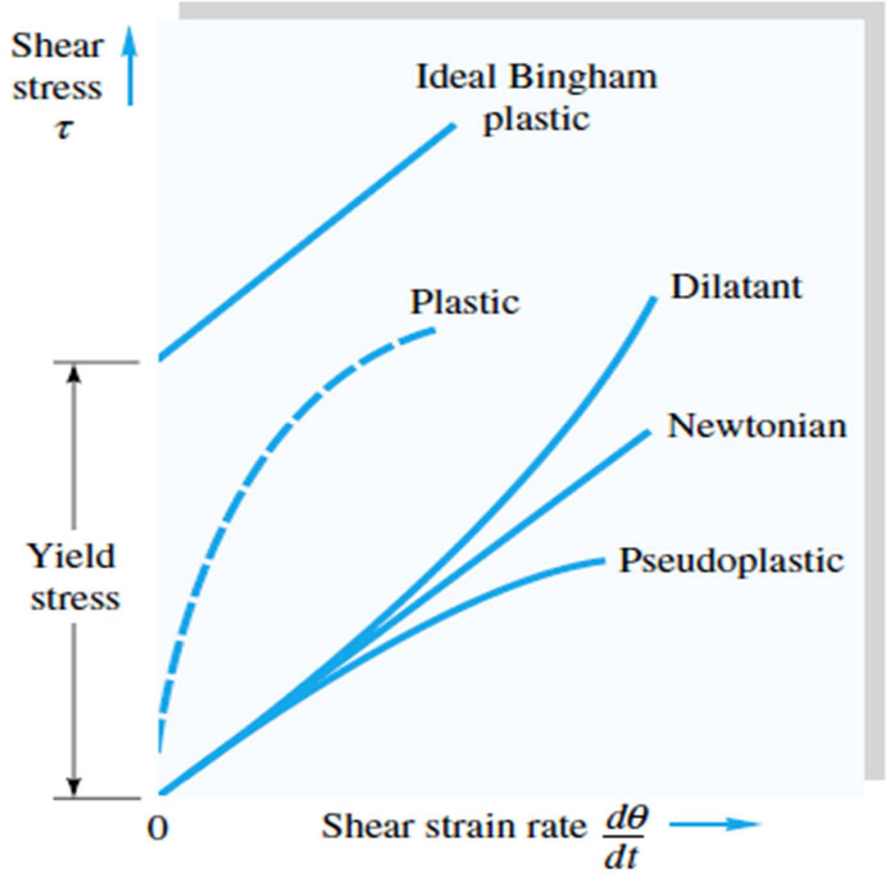


stress versus strain rate



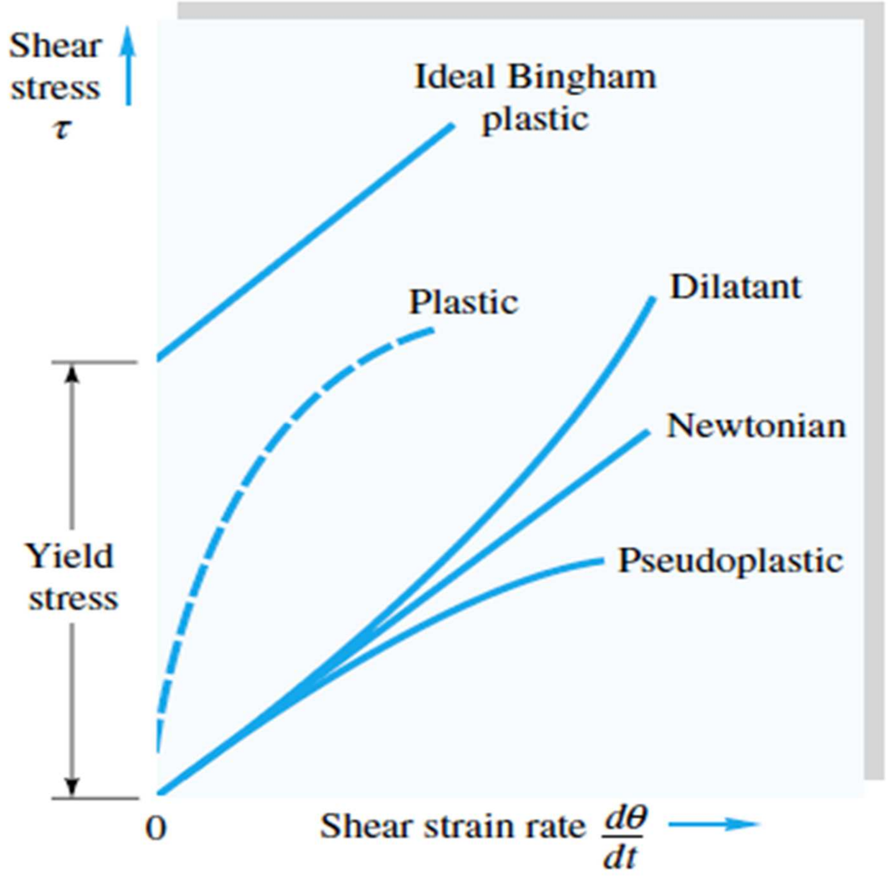
effect of time on applied stress

Yield stress



Graph from Frank M. White - *Fluid Mechanics*

Shear-thinning fluid



Graph from Frank M. White - *Fluid Mechanics*

Visco-elastic fluid

Summary

- Chapter 1: 1.1-1.7, 1.11
- Examples: 1.5,1.7-1.9
- Problems: 1.45, 1.47, 1.56

Sources

1. Face in the flame, *http://www.flickr.com*, photo courtesy of nEoPOL
2. Vortex wake, *http://www.airliners.net,* photo courtesy of S.C. Morris
3. Molten metal pouring, *http://www.flickr.com,* photo courtesy of Goodwin Steel Castings
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6. Pseudomonas fluorescens, *http://www.eoswetenschap.eu*
7. Aerial of the Copper River Delta Alaska, *http://www.lotofwallpapers.com*
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14. Eruption of Cleveland Volcano, *http://www.nasa.gov,* image courtesy of NASA
15. BP releases new spill video, *http://youtu.be/MLdAJn7YxeE*, video courtesy of Reuters
16. Archerfish, *http://www.news.uwa.edu.au ,* photo by Shelby Temple
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Illustrations from Frank M. White: *Fluid Mechanics*

Stills en movie fragments from Multimedia Fluid Mechanics DVD and Van Dyke, Album of Fluid Motion (www.efluids.com)